Upstream Migration
of the Glass-eel (Anguilla rostrata)
in Nova Scotia
- 1981 -

by

Susan J. Hutchison

Manuscript and Technical Report Series

Project Report No. 81-02

Nova Scotia
Department of Fisheries

Report No. 81-02

NOTE

Page order error:

Page	34	~~should be~~ has been	changed	to	page	30
"	30	"	"	"	"	31
"	31	"	"	"	"	32
"	32	"	"	"	"	33
"	33	"	"	"	"	34

Upstream Migration of the Glass-eel (*Anguilla rostrata*) in Nova Scotia - 1981 -

by

Susan J. Hutchison

Estuarine and Inland Fisheries
Nova Scotia Department of Fisheries

October, 1981

Table of Contents

	Page
Abstract	iii
List of Figures	iv
List of Tables	v
Introduction	1
Elver Life History	5
Part 1: Daily Elver Migration, Argyle River, Yarmouth County	6
Analysis of Elver Catch Numbers and Environmental Conditions	9
Analysis of Samples Collected from Daily Elver Catch	15
Part 2: Visual Observations of Elver Migration in Other Nova Scotian Waters	23
Analysis of Samples Collected from Visual Observation Checks on the Grand River, Richmond Co	25
Analysis of Samples Collected from Visual Observation Checks on the Ruisseau, Little and Inhabitants Rivers, Richmond County	~~30~~ 31
Summary	37
Closing Remarks	40
Bibliography	41

Acknowledgements

I am indebted to Lincoln MacLeod, Director of the Estuarine and Inland Division, who extended a liberal license to the project, thereby confirming his support of the research direction.

I would like to thank Marilyn Connor for her friendship, support and hard work given to myself and the project throughout the seven months. I would also like to thank Ivo Winter for his untiring assistance in the collection of field samples. I thank Bob Ottenbritte, Herb Dickinson and Moira Cavanagh for their technical assistance which was fundamental in completion of the project. I would like to thank Nina Pepper for her patience and expertise in the typing of this report.

Abstract

A study of elver migration on the Argyle River, Yarmouth County, was conducted from May 7 to June 10, 1981. Catch statistics indicate a total of 7,276-12,127 migrating elvers ascend via this route during the given period. This number is thought to be small. Significantly larger quantities of elvers were observed by fishermen following the study period. Temperature and tidal flow were found to be more influential than lunar period on elver migration. A wave of elvers is indicated from May 15 to June 6 by an increase in the degree of pigmentation of consecutive samples. Visual observations of migrating elvers were conducted on the Grand, Little, Ruisseau and Inhabitants Rivers, Richmond County. Samples from the Grand River picture changes in the elver population at a fixed location over a three month period. A new wave of elvers entering the area in late July is depicted by a drop in the degree of pigmentation displayed by the sample. Spot checks on elver populations in the other Richmond County rivers produced samples of similar description as those from the Grand River taken during the same time period.

List of Figures

Page

Figure 1: Biological cycle of the eel..... 7

2: Daily elver catch and temperature in the Argyle River..... 10

3: Data for variables from Argyle River..... 16

4: Percentage of individuals in each stage against time in the Argyle River..... 17

5: Variables for stages 4 and 5 against time in the Argyle River..... 19

6: Variables for stages 6-8 and 9 against time in the Argyle River..... 19

7: Locations of visual observation checks... 24

8: Data for variables from Grand River..... 26

9: Percentage of individuals in each stage against time in the Grand River..... 27

10: Variables for stages 6-8 and 9 against time in the Grand River..... 28

11: Clustered elvers..... ~~32~~ 33

12: Migrating elvers along shore..... ~~33~~ 34

List of Tables

Page

Table 1: Development of pigment in elvers..... 8

2: Data from daily monitoring of elver run in Argyle River..... 10

3: Data for variables from elvers in the Argyle River..... 16

4: Data for variables from elvers in the Argyle River..... 17

5: Data for variables from elvers per stage in the Argyle River..... 18

6: Visual observations of elvers in different locations..... 25

7: Data for variables from elvers in the Grand River..... 27

8: Data for variables from elvers per stage in the Grand River..... 28

9: Data for variables from elvers in the Ruisseau River..... ~~31~~ 32

10: Data for variables from elvers per stage in the Ruisseau River..... ~~31~~ 32

11: Data for variables from elvers in the Little River..... ~~32~~ 33

12: Data for variables from elvers per stage in the Little River..... ~~32~~ 33

Introduction

An interest in marketing of elvers has grown in recent years in response to increased eel culture operations in many countries. Activities of a profitable private enterprise to trap and sell young eels below the huge waterfalls at Trollhattan in Sweden have been well known since 1893. To date, all eel culture industries are dependent upon the limited natural stocks of glass-eels for culture initiation. Lack of information concerning the quantity and quality of elvers and the factors influencing their recruitment has caused officials to decline offers from outside consortiums to purchase Nova Scotian elvers. The instigation and management of an elver fishery may therefore be possible with increased knowledge of the population dynamics of the eel in Nova Scotia waters.

Elvers constitute the initial phase of eel life history in estuarine and inland waters. Information on elver numbers, distribution, growth and development is required for accurate assessment of present and future eel stocks. Knowledge of eel stock dynamics will aid an already growing fishery. Prospects for the 1982 season are enhanced by the demand for eels from lucrative European markets. Uncontrolled growth, however, will ensure only a speedy demise of provincial eel populations and any eel fishery will subsequently die.

The intentions of this investigation include the establishment of criteria from which one can assess the condition of populations of elvers sampled under known environmental conditions, i.e. pH, temperature, water depth, flow and salinity. It is possible, also, that the variables may serve in an assessment of the duration of time that has passed since their invasion of estuarine areas and freshwater lakes.

Upstream migration of elvers is considered in this report. To date no studies on the timing and intensity of elver migrations have been completed in Nova Scotia. Capture methods include the use of a new design of static and dynamic elver trap nets (Hutchison, unpublished). Biological investigations include monitoring of elver migration over time at fixed and varied locations.

In the first section, elvers were netted on an Argyle River tributary over a 36 day period. Numbers of migrating elvers netted daily were recorded in relation to changing environmental conditions. Samples of each catch were analyzed for length, weight, stage of maturity and otolith length. Indications of physiological changes of the elvers at a given time-location could thereby be established through observation of the relationships of the above variables. Specific indicators of elver growth progression might then be ascertained by selecting a variable or group of variables from

those monitored, which, when considered in future studies, might be used to describe the growth progress of a given population. Chances are, however, that criteria for comparing yearly runs will be confined to the local areas assessed and/or to periods exhibiting similar environmental conditions as those recorded during the present sampling period.

In the second section, elvers were taken from a larger river, Grand River, at only one location midway along the river's path from the sea to the first lake of the system. The catch location was situated immediately below a set of rapids which facilitated trapping of samples. The elvers were hindered in their migration at a point just below the falls and could be easily captured.

By sampling at this location over a longer time period it was hoped that one might establish a picture of a given population of elvers over the course of the summer. From the study of variables assessed in the first section, it was thought that one variable might prove to be slightly more independent than the others. If this proved to be the case, then that variable might be employed in descriptions of the population at a fixed location over time. Chances in the variable might be noted as movements of new elvers into the area or growth of those already established at the location.

The final section is a record of analyzed samples of different populations captured at separate locations. These spot checks served as limited estimates of the state and position of the populations at the time of sampling. Comparison of these samples with those from Grand River would be carried out. Results of this comparison would, therefore, be dependent upon the success of the Grand River stock monitor and serve as only a limited indication of the smaller population's development as compared with the Grand River stock.

Elver Life History

The life of an American eel (Anguilla rostrata) begins in the Sargasso Sea. Eel larvae captured in these waters are transparent, shaped like a willow leaf, and have small pointed heads and sharp teeth. Distribution of the larvae from the Sargasso to Nova Scotian waters is facilitated by the movements of the Gulf Stream. It is believed that the larvae (leptocephalus stage) undergo both active and passive swimming while in the Gulf Stream. Before the larvae undertake to bridge the roughly 160 kilometer gap from the Gulf Stream to coastal waters, they undergo a metamorphosis and are transformed into the glass eel (size range 5-8 cm). The body form now resembles the adult eel in shape but lacks pigmentation. It is better suited to the active swimming required for them to reach the coast.

Aided by tidal flow, the glass eels invade the estuarine areas and river systems as early as mid-March and continue to arrive into the summer months. They are known to initiate ascent in waves related to tide times and moon phases (Deedler, 19). Ascension into fresh water is broken into periods which allow time for their bodies to adapt to the change in salinity. Elvers mature into young eels during the summer and live where they find food. Some begin their ascent again in the spring

and continue to penetrate higher in a river system for up to 5 years. Their renewed upstream migration is due to a combination of feeding pressures and an olfactory stimulus to move to grounds of reduced populations.

Tesch (1973) has noted the remarkable olfactory capacity of the eel. Miles (1968) states that elvers are attracted by the odour of older eels. This reaction is thought to be partially instrumental in leading the elvers to suitable rivers. It is thought that this olfactory attraction is reversed as the elvers mature.

Elvers mature into young eels and live in estuarine and inland waters for up to 25 years. Environmental conditions dictate the onset of sexual maturation in the eel, which illicits a migratory response, causing the eel to return to the Sargasso Sea to complete the cycle. Figure 1 (modified after Finiger, 1976) diagrams the biological cycle of the eel.

Part 1

Daily Elver Migration, Argyle River, Yarmouth County

Materials and Methods:

An elver net (Hutchison, unpublished) was set in the tributary of the Argyle River running under bridge number one at Argyle Head. Hourly checks were made each

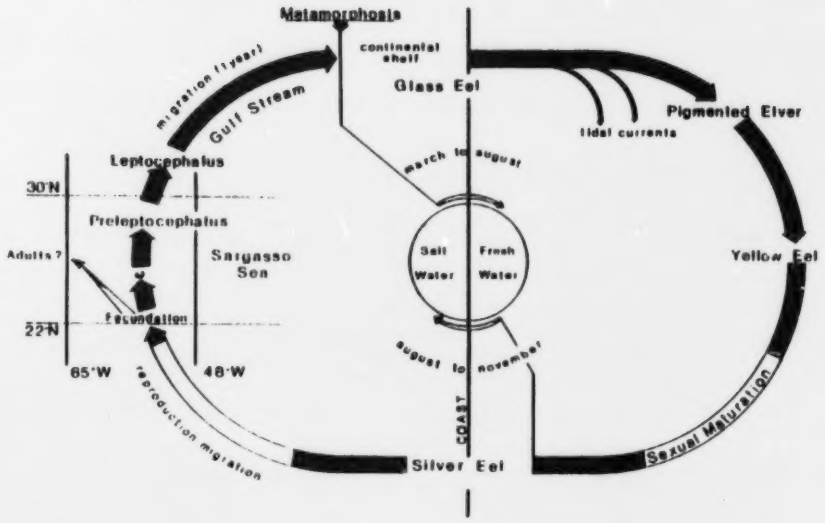


Figure 1: Biological cycle of the eel Anguilla rostrata

day beginning three hours before and continuing until three hours after dark high tide.* Measurements of pH, temperature, flow, milliliters of elvers, and the presence of other species were recorded. A sample of 30 elvers was taken each day. Samples were preserved according to Steedman (1976) for laboratory analysis.

In the laboratory, elver samples were staged according to Strubberg (1913). Stage descriptions are given in Table 1. Stage VIA_{IV} has been taken to three subdivisions as the majority of elvers fell in this category. The stages were assigned numbers as per Table 1,

*Migrations occurred on the rising flood tide and at full tide with virtually no movement during the ebb tide. Moon phases were not found to be as influential on elver movements as were tide times and temperature.

which have been used throughout this report to facilitate mean estimations. In the instances where samples were divided on the basis of stages, divisions were taken only to the stage i.e. sub-stages were not considered individually.

Table 1: Table of the development of pigment in elvers (abridged from Strubberg, 1911 and Tesch, 1977)

Stage of development of the pigment	assigned number	Characteristics	sub stage	Characteristics
VA	1	Metamorphosis complete, eel-like in form, no external pigment (glass eel) except the caudal spot.		
VB	2	No pigment on the back, body or tail region, except for the skull, caudal spots and some ventral pigment.		
VIA_I	3	Development of pigmentation along the whole dorsum, postanal dorsolateral pigment develops, no clear mediolateral pigment.		
VIA_{II}	4	No preanal ventrolateral pigment. Postanal development of mediolateral pigment.		
VIA_{III}	5	No preanal ventrolateral pigment. Clear preanal development of mediolateral pigment, postanally over almost entire dorsum, pigment rows along the myosepta and, in places, doubling of the mediolateral melanophores.		
VIA_{IV}	6	Pigment distributed for the most part along the myosepta. Distinct development of ventrolateral pigment preanally.	a	Distinct ventrolateral pigment, present preanally as scattered chromatophore under the mediolateral line. The postanal ventrolateral pigment is stronger, and is distributed along the myosepta. Doubling of the dorsal series (locally) also preanally.
	7		b	Ventrolateral pigment in hinder portion of preanal part of body distributed myoseptally. Increased doubling of the myoseptal and development of the intermyoseptal pigment, dorsally, and (postanally) ventrally.
	8		c	Distinct doubling of the preanal, ventrolateral myoseptal series and simultaneous development of the corresponding intermyoseptal pigment.
VIB	9	Pigment rows along the myosepta becoming indistinct. Lateral line still recognizable, as are the individual melanophores on the head, behind and below the eyes, and on the lower jaw.		

Length measurements were made with slide calipers and weights were taken with a Metler 1200 balance. Otoliths were removed at 12.5 magnification under a stereo microscope. They were measured for length using a slide micrometer and a graded ocular.

Analysis of Elver Catch Numbers and Environmental Conditions

Results:

Daily catches for the period from May 7 to June 11, 1981, water temperature for each high time fished, and pH values recorded previous to, during, and following catch high tides, are given in Table 2. Figure 2 illustrates the catches in milliliters of elvers against time in days and graphs the values over the plot of catch totals.

Discussion:

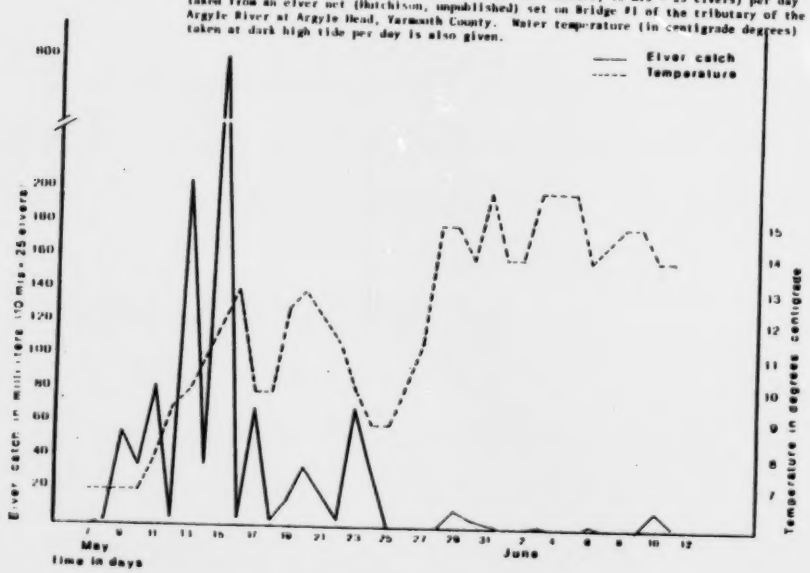
Daily catch results show an increase in ascending elvers from May 7 to 15, followed by a decline to zero by May 25. There were relatively few elvers captured for the subsequent two week period. During the initial week, the invasion appears to have peaked on a 48 hour cycle, as every second night yielded elvers while interim periods recorded only small numbers of elvers. The quantity of elvers is equal to 25 per 10 ml. Therefore, the maximum number of elvers captured during high tide is equal to 2,000 (May 15). The total number of elvers netted during the period from May 7 to 25 was 3,638 (Table 2, sum catch columns x 2.5). Consequently, the capture on May 15 represented approximately one-half of the total number of netted elvers. There were no elvers

Table 3 : Table 2 represents data from the monitoring of elver migration on a tributary of the Argyle River running under bridge number 1 at Argyle Head, Yarmouth County from May 7-June 11, 1981. Information includes the time of high tide in hours (tide time), total elver catch per high tide in milliliters (catch)*, water temperature at high tide (temp.) in degrees centigrade and the pH recorded by Hach kit 2 hours before (ht-2), during (ht), and 2 hours after (ht+2) high tide.

date	tide time hrs	catch mls	temp °C	pH			date	tide time hrs	catch mls	temp °C	pH		
				ht-2	ht	ht+2					ht-2	ht	ht+2
7	0025	0	7.0	5.70			25	0025	0	9.0	5.9	5.40	
8	0135	2	7.0				26	0315	0	11.5	6.2	5.30	5.7
9	0215	55	7.0	5.10	5.10		27	0425	0	11.5	5.5	5.80	5.8
10	0320	15	7.0	5.65			28	0525					
11	0425	82	8.0	5.20	5.20	5.70	29	1845	10.0	15.0	5.7	5.70	5.6
12	0540	5	9.5	5.30	5.30	5.60	30	1945	5.0	15.0	5.9	5.90	5.5
13	1905	205	10.0	5.40	5.09	5.10	31	2030	3.0	14.0	5.6	5.60	
14	2000	36	11.0	5.95	5.80	5.40	1	2130	0	16.0	5.4		
15	2045	800	12.0	5.80	5.80	6.00	2	2225	0	14.0	5.6	5.50	5.6
16	2115	4	11.0	5.90	5.90	5.50	3	2305	1.0	14.0	5.8	6.27	5.8
17	2200	69	10.0	5.30	5.50	5.30	5	0010	0	16.0	5.7	5.70	5.6
18	2240	3	10.0	6.20	5.80	5.80	6	0055	1.5	16.0	6.2	6.00	6.1
19	2300	15	12.5	5.20	6.00	5.50	7	0150	0	14.0	6.2	5.90	6.0
20	2345	35	11.0	6.20	5.90	6.00	8	0250	0	15.0	6.1	5.40	6.3
22	0025	4	11.5	5.80	5.50	5.90	9	0355	0	15.0	5.9	5.80	5.9
23	0055	70	10.0	5.65	5.69	5.89	10	0500	10.0	14.0	6.0	5.60	5.4
24	0135	35	9.0	5.95	6.00	5.45	11	0600	0	14.0	5.2	5.50	5.0

*10 milliliters of elvers equal 25 elvers.

Figure 2 Graphical representation of the elver catch (in milliliters, 10 mls = 25 elvers) per day taken from an elver net (Hutchison, unpublished) set on Bridge #1 of the tributary of the Argyle River at Argyle Head, Yarmouth County. Water temperature (in centigrade degrees) taken at dark high tide per day is also given.



observed prior to May 7 by local fishermen. It would appear from the catch statistics in Figure 2 that the elvers move as a body, with a percentage (in this case 22%) preceding the main group and a similar percentage following.

Total catch per day represents approximately 30-50% of the total number of elvers migrating in the tributary. This estimate is based on the percent area covered by the net and visual observation of the avoidance behavior of elvers in relation to it. It follows then that the total number of migrating elvers ascending via this route would equal 7,276-12,127 during the observed time period. Numbers of elvers several times greater than that indicated by the above figure are thought to pass up this system each year.

The tributary monitored by net was a minor tributary of the Argyle River system and is therefore believed to represent but a small percentage of yearly numbers of migrating elvers. During the two week period following May 25, elvers were observed on the major tributary. Prior to this date heavy fishing of gaspereau had occurred on the route. Consequently, netting of elvers there for research purposes was not possible as the commercial fishery held precedence. Were netting possible on this section, one would expect to have found significantly more

elvers passing than were observed on the small tributary, based on the difference in size and water flow between the larger and smaller sections.

The two week period from May 27 to June 11 produced virtually no elvers in the netted tributary. However, local fishermen sighted large quantities of elvers in the minor tributary approximately one week after this period. Their numbers were reported to have far exceeded those recorded during the netted period. Elvers were also sighted on the major tributary in large quantities.

In Figure 2 one can see an association between the increase in elver abundance with increasing temperature and a subsequent decrease in abundance with decreasing temperature from May 7 to 25. The relationship between elver invasion and temperature has been noted by other researchers (Jellyman, 1977a; Miles, 1968; Strubberg, 1913). Jellyman suggests that water temperature could affect both the start of the season and the intensity of the invasion. Nova Scotia experienced a particularly cold spring this year, and, prior to the setting of the net, water temperatures remained below $7^{o}C$. Visual observations by fishermen of elver migrations in previous years indicate that the climax of migration on the monitored tributary is often 2-3 weeks previous to that observed in 1981. It is possible then that the

onset of invasion was delayed this year by the cold temperatures.

The intensity of invasion appears to have been negatively affected by declining water temperatures from May 16 to 25. It is possible that the increase in catch per day from May 7 to 15 would have continued with favourable temperatures. A second wave of elvers in mid-June (previously mentioned) was significantly greater and may represent a number of individuals which would have migrated in the May invasion if temperatures had been more favourable. Timing and intensity of elver runs is known to differ significantly from year to year.

May 27 to June 11 saw increased temperatures with no corresponding increase in elver numbers on the minor tributary (Table 2). During and after this period elvers were noted in large numbers on the major tributary. At first, the elvers were probably attracted to the smaller tributary rather than the larger one since it was narrower, shallower, and consequently would have been warmed more quickly by early rises in temperature (May 7 to 26). Elvers also respond to differences in the rate of water flow in given systems by showing a preference for faster water. However, if the temperature is too cold in the faster water, the elvers choose slower waters with more desirable temperatures. As soon as the

faster waters warm to acceptable temperatures the elvers ascend via that route in preference over the smaller route.

Consequently, even as the temperatures rose again to acceptable levels in the minor tributary, May 27, the elvers did not resume migration via those waters but migrated via the major tributary.

A HACH kit was used for measuring pH values. However, the degree of sensitivity of this field instrument is questionable. The range of pH values obtained with the HACH kit lies between 5.09 and 6.20. Fluctuations varied significantly during the course of a single high tide, with differentials up to 0.6 recorded. The lowest values were concurrent with low tide and faster water. Slower water at high tide could possibly contain more particulate matter which may buffer the pH, resulting in a higher reading.

A local fish hatchery had been recording consistently lower pH values of 4.47 at a distance less than 0.5 km above the sampled location. They were measured under controlled laboratory conditions with more accurate instruments. The pH values recorded by our group in late August with a Fisher accumet pH meter model 156 were consistently low, 4.7 and 5.0 at low and high tides, respectively.

The effect of pH on elver invasion was investigated by Miles (1968), who found that it was not a dominant factor in the attractiveness of different streams to elvers. Our investigations were not designed to support or disagree with Miles' observations. The inclusion of pH, however, is always of interest when monitoring a population in the field. The immature elver, like the young of salmon and trout are at a fragile stage in their life cycle. They are affected by smaller changes in lowering pH values (increased acidity) than are the adults. Critical values of pH for young elvers have not been determined. It is possible that critical values lie within a range of 4.5-5.0. Recorded pH values in the Argyle River system do not fall far above this hypothetical range. Consequently, pH may be affecting the survival rates of elvers in the river. Harsh pH conditions may not directly kill the elvers but they may stress the organism causing a decline in its health. In this condition they would be more vulnerable to predation and less able to combat any diseases which are associated with young elvers.

Analysis of Samples Collected from Daily Elver Catch

Results:

Means for stage of maturity, length, weight, and otolith length, are graphed in Figure 3 (Tables 3

and 4 for samples collected in the Argyle River, Yarmouth County. The percentage of individuals at stages 6-9 for each sample is diagrammed in Figure 4 (Table 5). Figures 5 and 6 (Table 5) give means of length, weight, and otolith length for each stage category per sample per day.

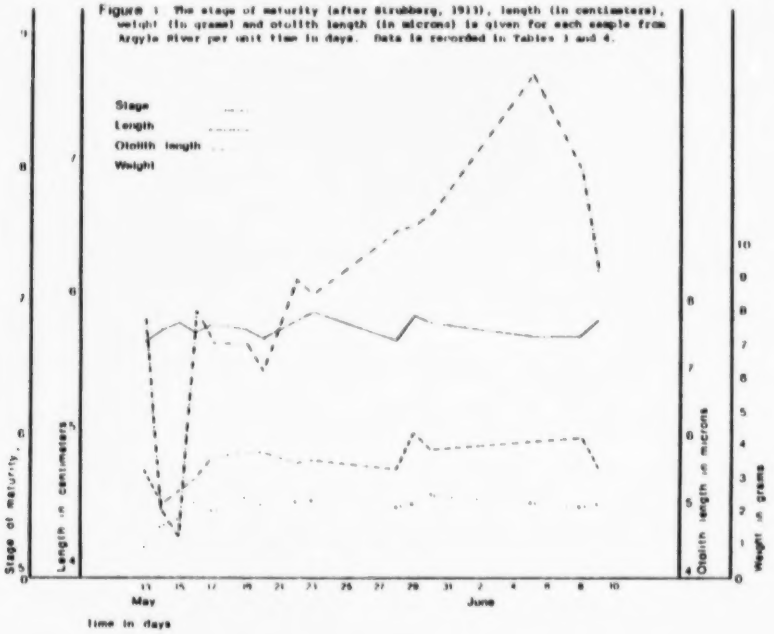


Figure 3 The stage of maturity (after Strubberg, 1913), length (in centimeters), weight (in grams) and otolith length (in microns) is given for each sample from Argyle River per unit time in days. Data is recorded in Tables 3 and 4.

Table 3 Statistics given are for variables length (in centimeters) and weight (in grams) obtained from samples captured on the tributary of the Argyle River, Yarmouth County. The sample size (n), mean, standard deviation (st. dev.), minimum (min.) and maximum (max.) values are recorded.

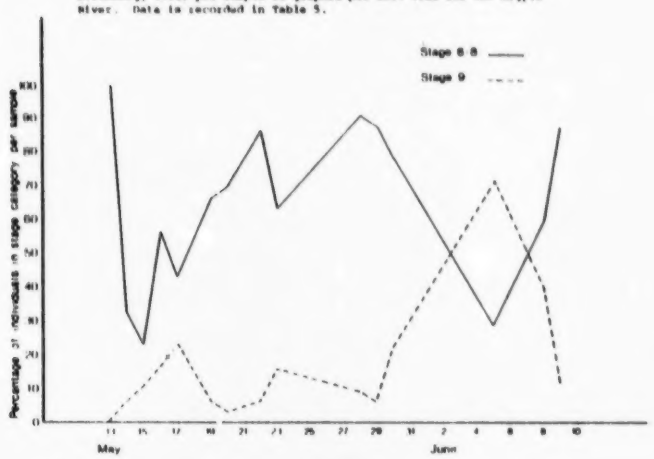
Date	Variable	length (in centimeters)				Variable	Weight (in grams)		
	n	mean	st dev	min	max	mean	st dev	min	max
5/13	16	5.668	0.160	5.39	5.86	0.090	0.018	0.06	0.12
5/14	30	5.754	0.570	5.20	6.82	0.157	0.039	0.10	0.28
5/15	30	5.803	0.575	4.49	6.42	0.177	0.029	0.12	0.23
5/16	30	5.742	0.414	5.05	6.68	0.228	0.040	0.15	0.32
5/17	30	5.801	0.301	5.22	6.39	0.205	0.048	0.13	0.32
5/19	30	5.763	0.347	5.17	7.06	0.239	0.078	0.17	0.61
5/20	30	5.690	0.244	5.14	6.26	0.222	0.036	0.16	0.30
5/22	30	5.818	0.351	5.14	6.48	0.227	0.039	0.14	0.32
5/23	30	5.877	0.261	5.37	6.48	0.232	0.037	0.17	0.32
5/28	11	5.677	0.236	5.36	6.09	0.214	0.044	0.16	0.29
5/29	17	5.855	0.261	5.29	6.35	0.223	0.031	0.17	0.28
5/30	9	5.801	0.275	5.44	6.26	0.247	0.047	0.15	0.29
6/05	7	5.709	0.116	5.57	5.90	0.225	0.028	0.19	0.27
6/08	5	5.700	0.332	5.29	5.98	0.210	0.041	0.15	0.26
6/09	8	5.821	0.412	5.36	6.34	0.220	0.027	0.20	0.27
6/10	1	5.880		5.88	5.88	0.350		0.35	0.35

Table 4 . Statistics given are for variables Otolith length (in microns) and Stage* obtained from samples captured on the tributary of the Argyle River, Yarmouth County. Sample size (n), mean, standard deviation (st. dev.), minimum (min.) and maximum (max.) values are given.

Date	Variable: Otolith Length (in microns)					Variable Stage			
	n	mean	st dev	min	max	mean	st dev	min	max
5/13	22	5.500	0.965	5.0	6.0	6.875	0.342	6.0	7.0
5/14	30	5.000	0.525	4.0	6.0	5.467	1.943	3.0	9.0
5/15	30	4.933	0.487	4.0	6.0	5.267	1.982	3.0	9.0
5/16	30	5.367	0.809	4.0	7.0	6.933	1.660	4.0	9.0
5/17	30	5.683	0.748	4.0	7.5	6.700	1.822	3.0	9.0
5/19	30	5.750	0.817	5.0	9.0	6.700	1.264	5.0	9.0
5/20	30	5.767	0.430	5.0	7.1	6.500	1.25	4.0	9.0
5/22	30	5.633	0.556	4.5	7.0	7.167	1.510	1.0	9.0
5/23	30	5.667	0.497	4.5	6.0	7.067	1.552	4.0	9.0
5/28	11	5.545	0.472	4.5	6.0	7.545	0.934	6.0	9.0
5/29	17	6.059	0.991	5.5	8.5	7.588	0.939	5.0	9.0
5/30	9	5.833	0.559	5.0	6.5	7.667	1.118	6.0	9.0
6/05	7	5.929	0.535	5.0	6.5	8.714	0.448	8.0	9.0
6/08	5	6.000	0.612	5.5	7.0	8.000	1.000	7.0	9.0
6/09	8	5.563	0.417	5.0	6.0	7.250	1.165	6.0	9.0
6/10	1	8.000		8.0	8.0	9.000		9.0	9.0

*Stages (after Strubberg, 1913) were given the following numerical values to facilitate analysis: VA=1, VB=2, VIA_I=3, VIA_{II}=4, VIA_{III}=5, VIA_{IV_a}=6, VIA_{IV_b}=7, VIA_{IV_c}=8, VIB=9.

Figure 4 The percentage of individuals in each stage category (after Strubberg, 1913)* per sample is graphed per unit time for the Argyle River. Data is recorded in Table 5.



*Stages (after Strubberg, 1913) were given the following numerical values to facilitate analysis: VA=1, VB=2, VIA_I=3, VIA_{II}=4, VIA_{III}=5, VIA_{IV_a}=6, VIA_{IV_b}=7, VIA_{IV_c}=8, VIB=9.

Table 3. The mean length (in centimetres), weight (in grams), otolith length (otolith lgth.) (in Microns), and the standard deviations for each variable, are given for each stage *(after Strubberg, 1913) per daily sample collected (date) from Argyle River. The percentage of individuals per stage per sample is also given (%).

date	% stage/n	stage	n	length cm	st dev	weight gm	st dev	otolith lgth microns	st. dev
5/13	100.0	6-8	22/22	5.668	0.160	0.090	0.018	5.500	0.365
5/14	13.3	3	4	5.980	1.000	2.270	1.000	6.000	1.000
	30.0	4	9	5.400	0.057	0.215	0.021	5.500	0.707
	16.7	5	5	4.301	2.655	0.240	0.046	4.071	2.009
	33.3	6-8	10	4.612	2.164	0.188	0.041	5.923	0.732
	6.6	9	2/30	5.883	0.299	0.191	0.050	4.429	2.423
5/15	20.0	3	6	6.021	0.267	0.182	0.023	4.833	0.606
	23.3	4	7	5.037	2.196	0.188	0.023	5.214	0.393
	23.3	5	7	5.074	0.336	0.186	0.033	4.714	0.267
	23.3	6-8	7	4.926	0.957	0.170	0.025	4.714	0.393
	10.0	9	3/30	5.700	0.413	0.153	0.049	5.667	0.289
5/16	10.0	4	3	5.630	0.621	0.210	0.030	4.500	0.000
	16.7	5	5	5.798	0.402	0.220	0.068	4.700	0.570
	56.7	6-8	17	5.119	1.792	0.231	0.036	5.853	3.151
	16.7	9	5/30	5.628	0.382	0.238	0.034	5.900	0.548
5/17	3.3	3	1	5.980		0.270		6.000	
	6.7	4	2	5.400	0.566	0.215	0.021	5.500	0.707
	23.3	5	7	4.301	2.655	0.240	0.046	4.071	2.009
	43.3	6-8	13	4.612	2.164	0.188	0.041	5.923	0.732
	23.3	9	7/30	5.883	0.299	0.191	0.049	4.429	2.423
5/19	26.7	5	8	4.415	2.566	0.215	0.035	5.625	0.744
	66.7	6-8	20	5.300	1.701	0.348	0.090	5.850	5.024
	6.7	9	2/30	5.780	0.170	0.255	0.078	5.250	0.354
5/20	3.3	4	1	5.480		0.210		5.000	
	23.3	5	7	5.780	0.292	0.237	0.042	5.786	0.267
	70.0	6-8	21	5.698	0.206	0.219	0.036	6.191	3.223
	3.3	9	1/30	5.140		0.200		5.500	
5/22	3.3	1	1	5.700		0.140		5.500	
	3.3	5	1	6.090		0.240		6.000	
	86.7	6-8	26	5.819	0.354	0.231	0.039	5.656	5.787
	6.7	9	2/30	5.980	0.156	0.235	0.007	5.250	0.354
5/23	6.7	4	2	5.870	0.212	0.220	0.000	5.250	0.354
	13.3	5	4	5.935	0.337	0.250	0.046	5.250	0.289
	63.3	6-8	19	5.884	0.192	0.229	0.027	5.694	0.519
	16.7	9	5/30	5.883	0.439	0.233	0.062	6.000	0.316
5/28	90.9	6-8	10	5.696	0.240	0.213	0.046	5.500	0.471
	9.1	9	1/11	5.490		0.240		6.000	
5/29	5.9	5	1	6.350		2.270		6.500	
	88.2	6-8	15	5.821	0.243	0.720	0.031	6.033	0.399
	5.9	9	1/17	5.860		0.220		6.000	
5/30	77.8	6-8	7	5.804	0.324	0.241	0.052	5.786	0.567
	22.2	9	2/9	5.805	0.064	0.265	0.007	6.000	0.070
6/05	28.6	6-8	2	5.896	0.014	0.300	0.040	6.000	0.000
	71.4	9	5/7	5.716	0.141	0.232	0.029	5.900	0.652
6/08	60.0	6-8	3	5.553	0.373	0.187	0.032	5.667	0.289
	40.0	9	2/5	5.930	0.028	0.245	0.021	6.500	0.707
6/09	87.5	6-8	7	5.789	0.321	0.216	0.264	5.571	0.450
	12.5	9	1/8	6.050		0.250		5.500	
6/10	100.0	9	1/1	5.880		0.350		8.000	
6/11	100.0	6-8	22/22	5.668	0.160	0.090	0.018	5.500	0.365

*Stages (after Strubberg, 1913) were given the following numerical values to facilitate analysis: VI=1, VII=3, VIA_I=4, VIA_{II}=4, VIA_{III}=5, VIA_{IV_a}=6, VIA_{IV_b}=7, VIA_{IV_c}=8, VIII=9.

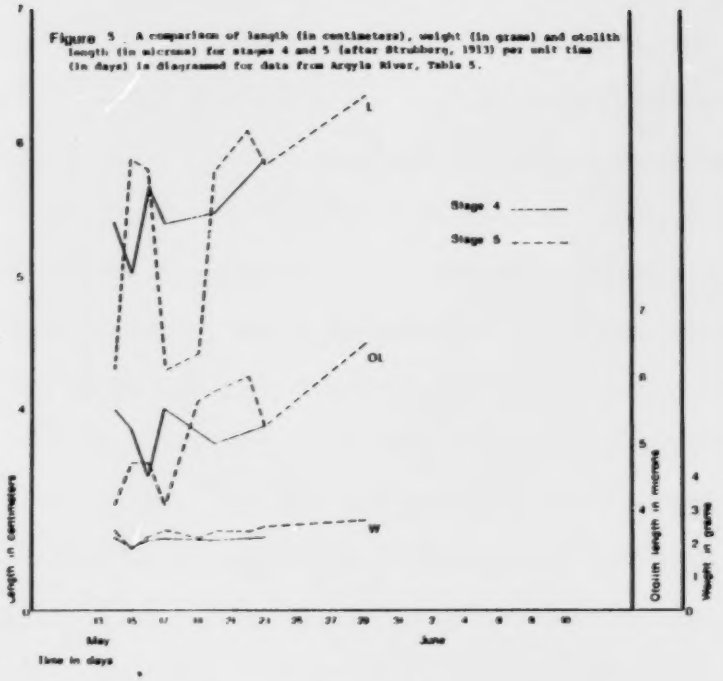


Figure 5 . A comparison of length (in centimeters), weight (in grams) and otolith length (in microns) for stages 4 and 5 (after Strubberg, 1913) per unit time (in days) is diagrammed for data from Argyle River, Table 5.

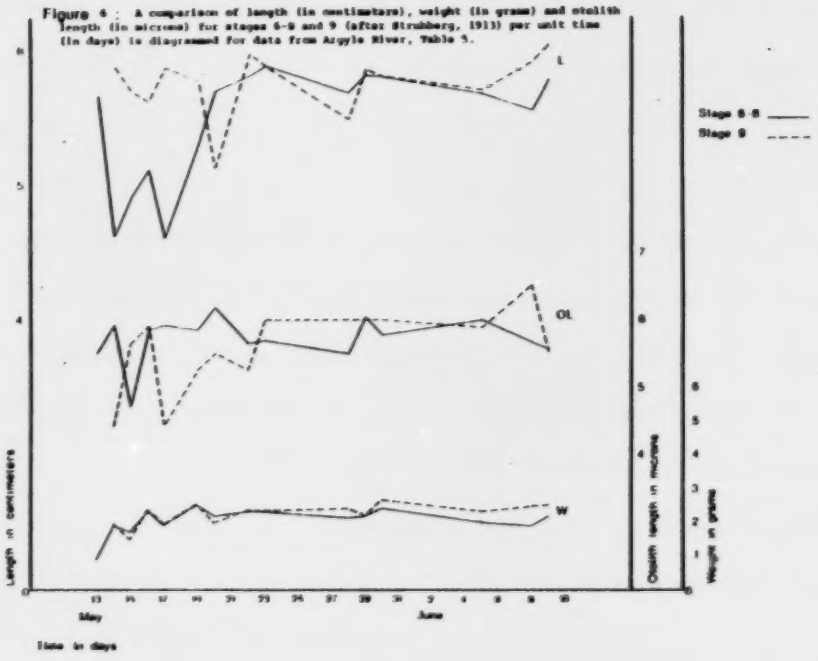


Figure 6 . A comparison of length (in centimeters), weight (in grams) and otolith length (in microns) for stages 6-8 and 9 (after Strubberg, 1913) per unit time (in days) is diagrammed for data from Argyle River, Table 5.

Discussion:

It was the intention of this investigation to establish if one or a group of variables may be used as an indicator of the condition of elvers which would serve in an assessment of the duration of time that had passed since the elvers began their invasion of estuarine areas and freshwater lakes. Pigmentation is used as an indication of physiological development in the elver. It is known that pigmentation proceeds at almost equal rates in both salt and fresh water (Jellyman, 1977b). Jellyman suggests, however, that the rate could be considerably modified by conditions of background coloration and temperature. Given that seawater in the coastal regions is colder, deeper, and therefore darker than in estuarine and river systems, one would predict that pigmentation would be retarded until elvers proceeded into estuarine and freshwater areas.

Looking at the stage of pigmentation, one might be able to determine when invasion into warmer, shallower waters began. If the elvers waited longer below a river before ascending, they would be more mature or pigmented. If they did not tarry long in these waters, they would be less pigmented at the same point along the river than those who waited.

In Figure 3 one can see the line drawn by mean stage of each sample. From this picture one might

interpret a series of events as follows. Elvers enter the coastal area in large numbers. Aided by tidal flow and drawn by olfactory stimulus, pH, temperature changes, and lunar cycles, some elvers begin their invasion almost immediately (May 15). Over the course of the next three weeks elvers initiate their invasion of fresh water at different times. They are all undergoing pigmentation at the same rate. Those waiting below the netted point are at the same pigmentation stage as those who would have passed through at an earlier time and been recorded (preserved) at an earlier stage. The elvers continue to initiate their ascent over the two to three week period, some staying longer in salt water for whatever reasons.

A few late stragglers come into the group from the ocean and initiate their ascent after the most mature elvers have gone (June 5). Their passage marks the end of the first wave (June 10). Some elvers from the group may be inhibited by cold temperatures and wait for the next group, or proper conditions to initiate their ascent. The end of a preceding wave is seen on May 13 and 14. A complete wave of elvers is described from May 15 to June 10.

The wave of elvers is best marked by the increase in the average maturity of elvers. A climax is denoted by a daily migration of 70% stage 9 elvers (Figure 4).

In both Figures 3 and 4 there is a reversion to a predominance of elvers in less mature stages after June 5. This coincides with a decrease in abundance of observed elvers as seen in Figure 2.

What then do length, weight and otolith length bring to light on the situation? Pigmentation is regarded as an indication of internal physiological changes such as are required for an organism to adapt from salt to fresh water. Bodily changes such as those in length, weight and otolith length might then be regarded in relation to the internal changes.

Means of the above recorded variables for each sample over time serve as indicators of the overall condition of a given migrating population. Graphic representation of the means picture changes in the relationships of the variables. In other words we might see one variable fluctuating, increasing or decreasing for a period in conjunction with, preceded by or following changes in one or more of the remaining variables. The timing of changes in relationships of variables to each other may draw a picture which could be interpreted as the events which are characteristic of the population at that time and location and under the observed environmental conditions.

In Figure 3, variables length, weight and otolith length indicate a degree of independence as compared

with stage. Mean stage of maturity per sample declines marginally in the initial two day period. The following 36 days see an increase in mean from 5.267 to 9.000. Average length of the samples increases fractionally from 5.668 to 5.880 cm, with the average of the length means being 5.772 cm. Mean otolith length increases from approximately 5.00 to 5.90 microns. Mean weight is constant at approximately 0.220 grams. June 8 initiates a negative drop in the mean stage which continues until the end of the observed period.

Even when broken down by stage of pigmentation (percentages of stage over time are given in Figure 4), the variable fluctuations do not lend themselves to lengthy interpretation. Elvers in lower stages exhibit greater fluctuation in variables length and otolith length in Figure 5. Variable fluctuations tend to stabilize in older stage 9 elvers (Figure 6). Much of the fluctuations in Figure 3 are accounted for in those described in Figures 5 and 6.

Part 2

Visual Observations of Elver Migration in Other Nova Scotian Waters

Materials and Methods:

Visual observations of inlets in Richmond County were conducted on the Ruisseau, Grand, Little, and Inhabitants Rivers. Samples from the Grand River were taken

at a point immediately below the rapids midway up the river between the sea and the first lake on the system. Capture of elvers was facilitated by the fast water there which hindered the elvers' progress and made them easier to catch. Samples were taken from the Grand River Falls on four occasions. These and samples from Little and Ruisseau Rivers were analyzed as per Materials and Methods in Part 1 of this Report.

Results:

Figure 7 and Table 6 describe the locations and results of observation checks.

Figure 7 Locations of visual observation checks for elvers. A=River Inhabitants, B=Ruisseau River, C=Grand River, D=Little River.

Table 6 : Visual observations of elvers in different locations of Nova Scotia

Location	date	figure 4	elvers sighted	sample collected	pH	Temperature °C
River Inhabitants						
Glenora	June 9	A	no	no	6.0	14
Ashilton	June 9	A	no	no	6.0	14
Cleveland	June 9	A	no	no	5.9	16
Ruisseau River	June 5	B	yes	yes	4.9	16
Ruisseau River	June 8	B	yes	yes	4.9	16
Grand River						
Grand River Village (GRV)	June 4	C	yes	yes	5.4	15.0
Grand River Falls	June 13	C	no	no	5.4	15.0
Grand River Falls			yes	yes	5.5	14.0
Grand River Falls	June 28	C	yes	yes	5.5	17.5
Loch Lomond			no	no	6	17.5
Grand River Vill.	July 20	C	no	no	5.65	18.5
Grand River Falls			yes	yes	5.5	18.5
Grand River Falls	August 14	C	yes	yes	5.5	19
Little River	June 8	D	yes	yes	4.9	15

Results from Grand River observations and sample analysis are presented and discussed. Results from spotchecks on Ruisseau and Little Rivers are presented and discussed following the analysis of samples from the Grand River under the heading, "Analysis of Samples Collected from Visual Observation Checks on the Ruisseau and Little Rivers, Richmond County".

Analysis of Samples Collected from Visual Observation Checks on the Grand River, Richmond Co.

Results:

Results of the analysis of samples collected below the fish ladder of the Grand River, Richmond County

are presented in Figure 8 (Table 7). Mean lengths decrease initially before turning in a positive direction to achieve an overall increase with time. Mean weight remains constant. Otolith length means increase with length increase. Mean stage per sample increases gradually. The sample of July 20 is fairly immature in relation to those preceding it and causes a dip in the increase. Mean stage is again recovered in August.

The percentage of individuals in each stage category per sample is given per unit time in Figure 9 (Table 8). Figure 10 (Table 8) depicts a comparison of the means per sample of the variables length, weight and otolith length for stages 6-8 and 9.

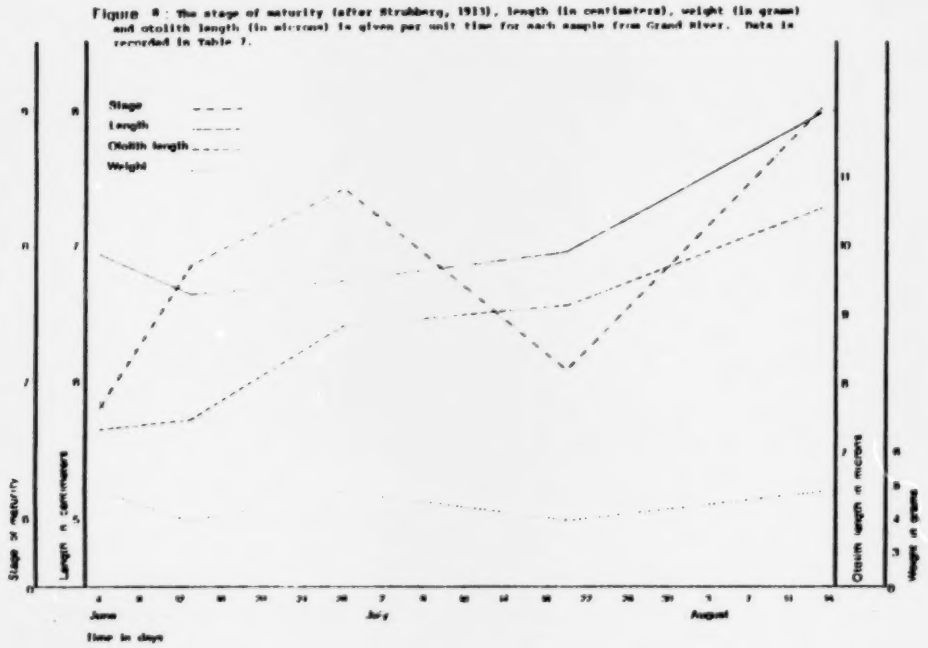


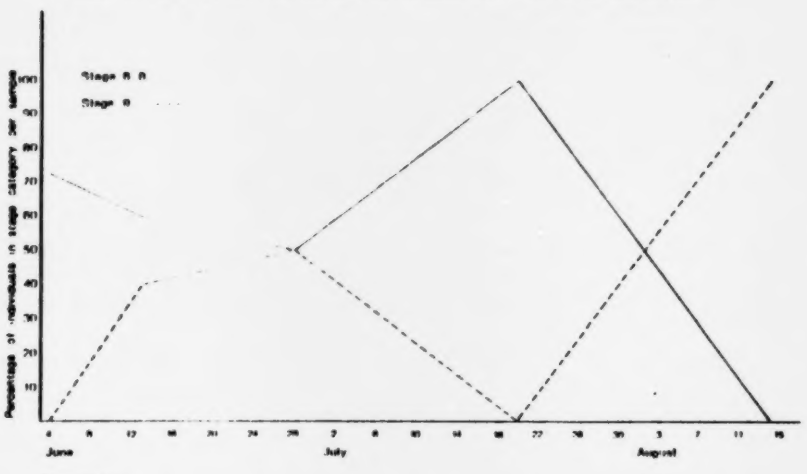
Table 7 Statistics given are for variables length (in centimeters), weight (in grams), otolith length (in microns) and stage* obtained from samples captured in the Grand River, Richmond County. Sample size (n), mean, standard deviation (st. dev.), minimum (min.) and maximum (max.) values are given.

Date	Variable Length (in centimeters)					Variable Weight (in grams)			
	n	mean	st dev	min	max	mean	st dev	min	max
6/04	11	6.935	1.192	5.84	9.40	0.485	0.268	0.19	0.93
6/11	30	6.653	0.766	5.25	7.93	0.394	0.205	0.10	0.90
6/28	38	6.743	0.991	5.36	10.71	0.479	0.328	0.16	1.81
7/20	22	6.965	0.547	6.09	8.16	0.393	0.173	0.12	0.76
8/14	22	7.975	0.953	6.51	9.75	0.484	0.187	0.18	0.90

Date	Variable Otolith Length (in microns)					Variable Stage			
	n	mean	st dev	min	max	mean	st dev	min	max
6/04	21	7.310	1.814	4.5	9.5	6.810	1.662	4.0	8.0
6/11	30	7.450	2.106	4.0	11.5	7.067	1.137	6.0	9.0
6/28	38	8.816	2.219	4.5	15.5	8.421	0.642	7.0	9.0
7/20	22	9.136	1.091	6.0	11.0	7.091	0.294	7.0	8.0
8/14	22	10.591	1.250	9.0	13.0	9.000	0.000	9.0	9.0

*Stages (after Strubberg, 1913) were given the following numerical values to facilitate analysis: VA=1, VB=2, VIA_I=3, VIA_{II}=4, VIA_{III}=5, VIA_{IV_a}=6, VIA_{IV_b}=7, VIA_{IV_c}=8, VIB=9.

Figure 4 - The percentage of individuals in each stage category *(after Strubberg, 1913) per sample is graphed per unit time (in days) for the Grand River. Data is recorded in Table 8.



*Stages (after Strubberg, 1913) were given the following numerical values to facilitate analysis: VA=1, VB=2, VIA_I=3, VIA_{II}=4, VIA_{III}=5, VIA_{IV_a}=6, VIA_{IV_b}=7, VIA_{IV_c}=8, VIB=9.

Table 8 The mean length (in centimeters), weight (in grams), otolith length (otolith lgth.) (in microns), and the standard deviations for each variable, are given for each stage *(after Strubberg, 1913) per daily sample collected (date) from Grand River. The percentage of individuals per stage per sample is also given (%).

date	% stage/n	stage	n	length cm	st dev	weight gm	st dev	otolith lgth microns	st dev
6/04	18.2	4	2	5.955	0.134	0.245	0.007	5.750	0.354
	9.1	5	1	5.640	1.000	0.190	1.000	5.000	1.000
	72.7	6-8	8	7.343	1.150	0.583	0.251	8.000	1.669
			11						
6/13	60.0	6-8	18	5.629	1.996	0.277	0.148	6.528	1.966
	40.0	9	12	7.273	0.485	0.570	0.143	9.000	1.087
			30						
6/28	50.0	6-8	19	6.464	0.655	0.362	0.162	7.553	2.488
	50.0	9	19	7.031	1.196	0.596	0.407	9.816	2.103
			38						
7/20	100.0	6-8	22	7.110	0.623	0.393	0.173	9.136	1.093
			22						
8/14	100.0	9	22	7.975	0.953	0.484	0.187	10.591	1.250
			22						

*Stages (after Strubberg, 1913) were given the following numerical values to facilitate analysis: VA=1, VB=2, VIA_I=3, VIA_{II}=4, VIA_{III}=5, VIA_{IV_a}=6, VIA_{IV_b}=7, VIA_{IV_c}=8, VIB=9.

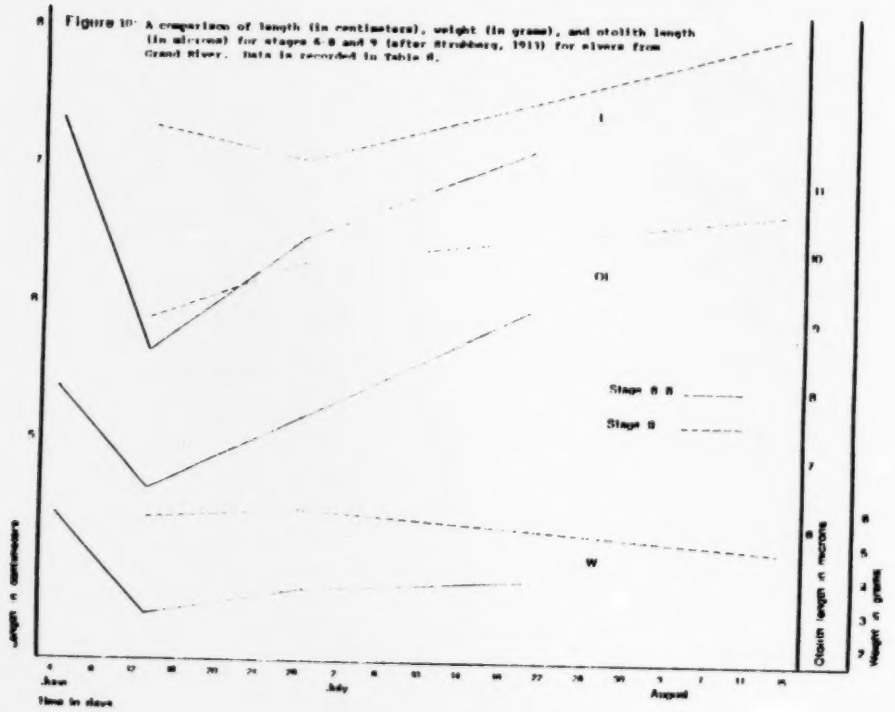


Figure 10 A comparison of length (in centimeters), weight (in grams), and otolith length (in microns) for stages 6-8 and 9 (after Strubberg, 1913) for elvers from Grand River. Data is recorded in Table 8.

Discussion

In Part 1 it was established that by monitoring the stage of pigmentation of migrating elvers one could estimate the length of time that the elvers had been in warmer, shallower water.

In Figure 8 one is able to observe alterations in the stage of pigmentation percentages over time. A continuous decline of less mature elvers during the initial period was interrupted in late July by a reversal to predominately lower staged elvers, (Figure 9). This is taken to represent the arrival to the area of a new wave of elvers. New arrivals, although less mature, exhibited positive physical growth in line with that exhibited by the previous wave (refer to Figure 8). They were perhaps the same age but may have been delayed in the initiation of the maturation process as denoted by the degree of pigmentation. Such a delay may be explained by considering the longer period of time that the new wave of elvers had been in colder deeper water. The effects of temperature and water depth on pigmentation were discussed in Part 1.

The stage 9 elvers in Figure 10 are recorded as exhibiting a weight loss over time. This reduction in weight is consistent with results obtained by Strubberg (1913) and Jellyman (1977b). Jellyman suggests

intervals between trappings. Grand River is not heavily fished for eels in contrast to the Argyle River. Future studies on the two river systems would yield valuable information on the effects of eel fishing on elver populations if sampling intentions and practices were the same for both rivers.

Analysis of Samples Collected from Visual Observation Checks on the Ruisseau, Little and Inhabitants Rivers, Richmond County

Results:

Tables 9 and 10 list statistics for the variables length, weight, otolith length, and stage of maturity obtained per sample captured in the Ruisseau and Little Rivers, respectively. Tables 11 and 12 relate data per stage for each sample for length, weight, and otolith length means from the Ruisseau and Little Rivers, respectively.

Discussion:

The observed inlet on the Ruisseau River is the only waterway feeding Grand Lake, located in the interior of Isle Madame. Construction of a road over the outlet has caused an increased flow of water out of the two access culverts. Elvers were clustered in the still waters below this point (Figure 11). There were approximately 2000 ml or 5000 elvers on both sides of the river, and more lined the banks. Their numbers darkened the

Table 9 Statistics given are for variables length (in centimeters), weight (in grams), otolith length (in microns) and stage* obtained from samples captured in the Bulsseau River, Richmond County. Sample size (n), mean, standard deviation (st. dev.), minimum (min.) and maximum (max.) values are given.

Date	Variable: Length (in centimeters)					Variable: Weight (in grams)			
	n	mean	st dev	min	max	mean	st dev	min	max
6/05	30	5.704	0.308	5.23	6.66	0.144	0.037	0.08	0.26
6/08	32	5.619	0.201	5.26	6.24	0.134	0.027	0.08	0.19

Date	Variable: Otolith Length (in microns)					Variable: Stage			
	n	mean	st dev	min	max	mean	st dev	min	max
6/05	30	5.300	0.385	4.5	6.0	6.700	0.702	5.0	8.0
6/08	32	5.172	0.350	4.5	5.5	6.750	0.508	6.0	8.0

*Stages (after Strubberg, 1913) were given the following numerical values to facilitate analysis: VA=1, VB=2, VIA_{I}=3, VIA_{II}=4, VIA_{III}=5, VIA_{IVa}=6, VIA_{IVb}=7, VIA_{IVc}=8, VIB=9.

Table 10 Statistics given are for variables length (in centimeters), weight (in grams), otolith length (in microns) and stage* obtained from samples captured in the Little River, Richmond County. Sample size (n), mean, standard deviation (st. dev.), minimum (min.) and maximum (max.) values are given.

Date	Variable: Length (in centimeters)					Variable: Weight (in grams)			
	n	mean	st dev	min	max	mean	st dev	min	max
6/08	30	5.616	0.389	4.8	6.6	0.177	0.036	0.11	0.25

Date	Variable: Otolith Length (in microns)					Variable: Stage			
	n	mean	st dev	min	max	mean	st dev	min	max
6/08	30	4.933	0.388	4.0	6.0	5.600	1.476	1.00	8.00

*Stages (after Strubberg, 1913) were given the following numerical values to facilitate analysis: VA=1, VB=2, VIA_{I}=3, VIA_{II}=4, VIA_{III}=5, VIA_{IVa}=6, VIA_{IVb}=7, VIA_{IVc}=8, VIB=9.

Table 11. The mean length (in centimeters), weight (in grams), otolith length (otolith lgth.) (in Microns), and the standard deviations for each variable are given for each stage *(after Strubberg, 1913) per daily sample collected (date) from Ruisseau River. The percentage of individuals per stage per sample is also given (%).

date	% stage/n	stage	n	length cm	sl. dev.	weight gm	sl. dev.	otolith lgth. microns	sl. dev.
6/05	3.3	5	1	5.330		0.110		6.000	
	96.6	6-8	29/30	5.545	1.063	0.146	0.037	5.276	0.368
6/08	100.0	6-8	32/32	5.463	0.901	0.134	0.027	5.172	0.350

Table 12: The mean length (in centimeters), weight (in grams), otolith length (otolith lgth.) (in Microns), and the standard deviations for each variable are given for each stage *(after Strubberg, 1913) per daily sample collected (date) from Little River. The percentage of individuals per stage per sample is also given (%).

date	% stage/n	stage	n	length cm	sl. dev.	weight gm	sl. dev.	otolith lgth. microns	sl. dev.
6/08	3.3	1	1	5.680		0.150		5.000	
	16.7	4	5	5.456	0.379	0.188	0.018	4.900	0.418
	23.3	5	7	5.419	0.398	0.160	0.037	4.714	0.393
	53.3	6-8	16/29	5.741	0.371	0.182	0.039	5.024	0.374

*Stages (after Strubberg, 1913) were given the following numerical values to facilitate analysis: VA=1, VB=2, VIA_I=3, VIA_{II}=4, VIA_{III}=5, VIA_{IV_a}=6, VIA_{IV_b}=7, VIA_{IV_c}=8, VIV=9.

shoreline for 3 m downstream (Figure 12). Elver sightings above the culverts were positive for 500 m upstream. Their numbers, however, were few and intermittent.

Figure 11: Elvers clustered in the still waters below culverts on the Ruisseau River, Richmond County.

Downstream observations were positive for 20 m. No elvers were observed at the bridge crossing the junction of fresh and salt water approximately 0.75 km from the culverts. Subsequent checks made along the length of the river resulted in negative sightings below the culverts and positive sightings above. After 8 days the majority of elvers had migrated more than 500 m upstream and only a trickle remained along the banks. Observations indicate that the elvers migrate in a wave similar to that recorded in the Argyle River tributary.

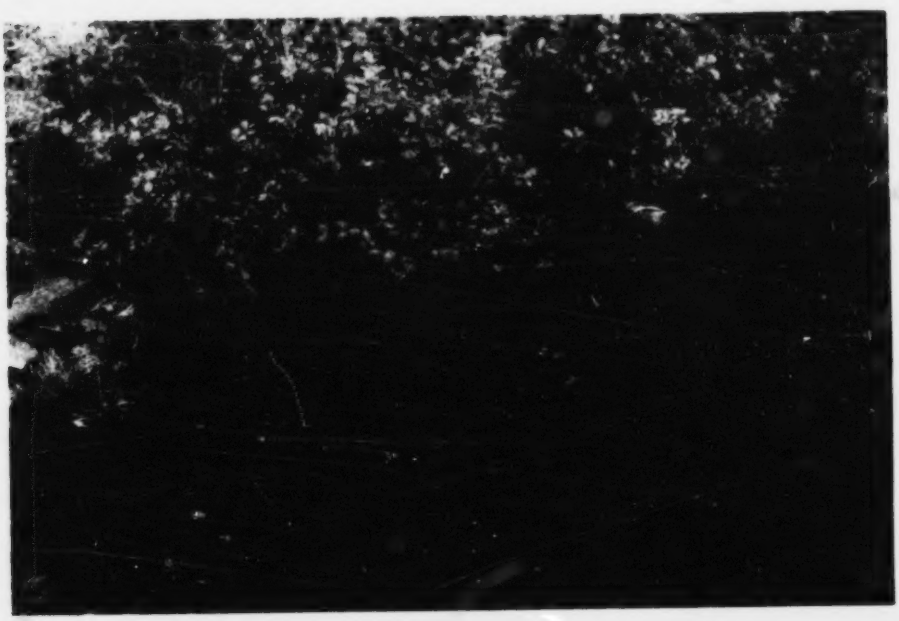


Figure 12: Migrating elvers darken the shoreline and waters of the Ruisseau River, Richmond County.

that weight loss is the result of a decreased percentage of body fluid in maturing elvers. It has been generally supposed that this is merely the completion of larval metamorphosis where shrinkage is principally due to loss of water (Callamand 1943). Unlike the results found by Jellyman and Strubberg, the data in Figure 10 shows only a short decline in length with weight. After June 28 length increases as weight decreases.

One sees in Figure 8 an increase in mean length and otolith length of the elvers, with no change in mean weight. With this elongation of the elvers, they assume an eel like appearance. In larger eels there is a significant correlation between otolith and fish length (Applebaum and Hecht, 1978). No similar correlation was found for leptocephali and elvers because of their similar total length (ibid.). During the first month of the present study, the elvers were seen to exhibit no correlation between length and otolith length. Elvers from July through August are proportionately longer and begin to display a correlation between length and otolith length. Should data be collected at smaller time intervals and similar results obtained, one might observe when the correlation between length and otolith length begins in the first season after elvers migrate into fresh water.

Data from the Grand River sampling would have benefited from increased catches of elvers with shorter

Little River lies just south of the Inhabitants River and is much smaller in size. The sample of elvers taken here was facilitated by a road culvert. Increased flow of water inhibited the passing of elvers somewhat, causing a buildup in the area. No attempt was made to observe downstream. Upstream, there is a man-made land dam constructed to create a reservoir. Migration from the end of the river to the lake (50 m) would be possible only during a rain as the dry ground at other times would cause fatal damage to the protective slime coat of an elver.

The population samples observed in Tables 9, Ruisseau River, and 10, Little River, do not differ significantly in length, weight, andotolith length from those obtained for the same time period on the Grand River. Stage of pigmentation data for the Grand River records the elvers in that location as being more advances physiologically than those from the Ruisseau and Little Rivers. Data from June 8 in Tables 11 and 12 for the Ruisseau and Little Rivers, respectively, may be compared with data from June 13 in Table 8 from the Grand River. Table 11 shows 100 percent of the elvers in stage 6-8 for the Ruisseau River. Table 12 shows 53.3 percent of the elvers in stage 6-8 with the remaining percent in less advanced stages 1-5 for the Little River. Table 8 shows 60 percent of the elvers in stage 6-8 and 40 percent in stage 9 for the Grand River.

The latter groups of elvers may not have been as long out of the coastal waters. It may be that the attraction of the larger Grand River is substantially greater than the two smaller rivers. Movement of elvers into the more attractive location would then precede movement into the smaller streams, thereby accounting for the observed difference in stage of pigmentation.

One might assume that all elvers taken in this region, Grand, Little and Ruisseau Rivers, originate from the same parent group, which separated after reaching shallower coastal water. This scenario is supported by observation of similarities in length, weight, and otolith length. Development of these variables proceeded at the same rate. Differences in the ascent initiation times are believed to have caused the fluctuation in pigmentation development between areas.

Elver checks conducted by boat on the Inhabitants River were negative. Likewise, spot checks at the West Bay Road Cross, Askilton, Glenora and the railway crossing showed no signs of elvers. The size of the river leaves one to believe that we were unable to locate their presence because of the ample room available for elvers to dissipate in response to movement.

Summary

1. Part 1

A monitor of the daily elver migration on the Argyle River, Yarmouth County was accomplished through the use of elver trap nets. Catch statistics during the observed period (May 7 to June 10, 1981) indicate an estimated total of 7,276-12,127 elvers ascend the Argyle River tributary in one wave. This wave may be followed by one of larger magnitude. The number of elvers in the observed wave represents but a fraction of the total number of migrating elvers which pass up the Argyle system via the monitored tributary. Temperature was seen to have a strong influence over elver migrations' timing and intensity.

2. Samples collected from the monitoring of the daily elver migration in the Argyle River, Yarmouth County were analyzed. From the changes in values of length, weight, otolith length and stage of pigmentation for samples over time, it was established that stage of pigmentation may be used as a measure of the timing and events of elver migrations. The remaining variables are seen to represent a picture of the growth of elvers during their migratory movements.

3. Part 2

Visual observations of migrating elvers in

Richmond County were conducted on the Grand, Little, Ruisseau and Inhabitants Rivers. Photographs depict their movements on the Ruisseau River. Temperature and pH were recorded per check.

4. Samples collected from the visual observation checks on the Grand River, Richmond County were analyzed. Stage of pigmentation was employed as an indicator of the timing and events of the elver migration. The data picture changes in the elver population at a fixed location over the summer months. Length and otolith length are correlated from July onward but show no relationship prior to this time. A new wave of elvers entering the area in late July is described by a drop in the degree of pigmentation displayed by the sample. New arrivals are thought to be the same age as those of earlier samples, indicated by similarities in growth variables from previous samples collected in the river.

Weight loss in stage 9 elvers is possibly merely the completion of larval metamorphosis where shrinkage is principally due to loss of water (Callamand, 1943).

5. Data from samples analyzed from the Ruisseau and Little Rivers, Richmond County agree with that from the Grand River, Richmond County. All three areas were

sampled during the same time period. Differences in the mean stage of pigmentation of the samples indicate a difference in ascension initiation times into the rivers.

Closing Remarks

Information on the glass eel movements and population numbers is limited throughout the eastern seaboard and into the St. Lawrence River. Glass eels are the sole source of recruits for a growing eel fishery and as such warrant further investigation. Elver and eel dynamics reviewed form the basis for realistic management practices in our eel fishery. Eels fished commercially range in age from 8 to 18. If poor practices reduce the mean age of the population below this range, the fishery will suffer. Reestablishment of a population following such an event would require upwards of 8-10 years.

Our eel fishery is just beginning to develop towards its potential. An actual value of the potential has yet to be firmly established; however, we have other fisheries throughout the world from which we can learn. It is possible that activities such as limited culturing and stocking practices will be included in future eel fishery programs. Information gained through this report may be used in such endeavours. It will also serve as a resource upon which future investigations may be based.

Bibliography

Appelbaum, S. and T. Hecht (1978). Otolith length/fish length relationship of leptocephali, elvers, and sub-adult (reared) eels Anguilla anguilla. Environmental Biology of Fishes 3 (2), 245-247.

Callamand, O. (1943): l'Anguille Europeenne. Les bases physiologiques de sa migration. Annales de l'institut Oceanographique 21: 361-440.

Deedler, C.L. (1958). On the behavior of elvers (Anguilla Vulgaris Turt.) migrating from the sea into fresh water. International Council for the Exploration of the Sea. Journal du Conseil. 24: 135-146.

Finiger, R. (1976). Contribution a l'etude biologique et ecologique des Civilles (Anguilla anguilla) lors de leur penetration dans un etang mediterraneen: recruitment et biometrie au cours d'un cycle annuel. Vie Milieu, 26 (1A), p. 123-144.

Hutchison, S.J. (Unpublished). Elver Trap Nets. Nova Scotia Department of Fisheries, P.O. Box 2223, Halifax, N.S., Canada B3J 3C4

Jellyman, D.J. (1977a). Summer upstream migration of juvenile freshwater eels in New Zealand. New Zealand Journal of Marine and Freshwater Research 11 (1), p. 61-71.

Jellyman, D.J. (1977b). Upstream migration of glass-eels (Anguilla spp.) in the Waikato River. New Zealand Journal of Marine and Freshwater Research 13 (1), p. 13-22.

Miles, S.G. (1968). Rheotaxis of elvers of the American eel (Anguilla rostrata) in the Laboratory to water from different streams in Nova Scotia. Canada Fisheries Research Board Journal, 25 (8), p. 1591-1602.

Steedman, H.F. (1976). Some technical aspects of lepto-cephalus fixation and preservation. In Monographs on Oceanographic Methodology, Zooplankton Fixation and Preservation, H.F. Steedman (ed.). Unesco Press, Paris, 1976.

Strubberg, A. (1913). The Metamorphosis of Elvers as Influenced by Outward Conditions. Danmares Fisk-eriog Havundersgelser, Serie Fiskeri, 4, p. 1-11.

Tesch, F.W. (1973). The Eel. Chapman and Hall, London.